Robert Grosseteste on Light, Truth and Experimentum

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In outlining the major shifts in the practice of natural philosophy which contributed to the rise of modern science, one might point to two developments as being of particular importance: the increased use of experiment, namely the contrived observation of nature rather than mere Aristotelian *empeiria*; and the wider deployment and increasing sophistication of mathematics. Is it possible to find any traces of such practices in the mediaeval schools?[1] It has been argued that in the work of two Oxford Franciscans, Robert Grosseteste (c. 1170-1253) and Roger Bacon (c. 1220-c. 1292),[2] one finds both the practice of experimental observation (the *experimentum* or *scientia experimentalis*) in the confirmation and falsification of hypotheses, and the more ready use of mathematical analysis.[3] This

[1] The relationship between mediaeval natural philosophy and modern natural science is much contested. See, for example, P. Duhem, *Le Système du Monde: Histoires des doctrines cosmologiques de Platon à Copernic* (10 vols), Paris 1913-1959. Duhem focuses particularly on the continuity between Aristotelian science and early modern physics. For a précis of Duhem's view, see his essay *History of Physics* in: P. Duhem, (ed. and trans. R. Ariew and P. Barker), *Essays in the History and Philosophy of Science*, Indianapolis 1996, 163-221. Of those who contest the 'continuity thesis', a prominent example is A. Maier (ed. and trans. S. D. Sargent), *On the Threshold of Exact Science: selected writings of Anneliese Maier on late medieval natural philosophy*, Pennsylvania 1982. For a recent discussion of many pertinent issues, see M. J. Osler (ed.), *Rethinking the Scientific Revolution*, Cambridge 2000.

[2] Although Grosseteste was closely associated with the Franciscans, becoming their first Lector in Oxford around 1230 in the years before taking the See of Lincoln, he never joined the Order. Bacon took the habit around 1257. See R. Southern, *Robert Grosseteste: The Growth of an English Mind in Medieval Europe*, Oxford 1986, ch. 4 and A. Little, *Introduction: On Roger Bacon's Life and Works*, in: A. Little (ed.), *Roger Bacon: essays contributed by various writers on the commemoration of the seventh century of his birth*, Oxford 1914, 1-32.

[3] The suggestion that Bacon, in particular, was the founder of experimental science is found in the comments of the nineteenth century mathematician and scientist William Whewell who wrote that 'Roger Bacon's works are not only so far beyond his age in the knowledge which they contain, but so different in the temper of the times, in his assertion of the supremacy of experiment, and in his contemplation of the future progress of knowledge, that it is difficult to conceive how such a character could then exist.' (W. Whewell, *History of the Inductive Science*, 2 vols, New York 1858, 3rd ed., vol. 1, 245). It became commonplace in the later nineteenth and early twentieth centuries to develop this assessment of Bacon which was itself derived from the praise given by his namesake Francis Bacon, a writer who was otherwise disparaging about mediaeval natural philosophy. For particu-

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distinguishes their approach from the various Aristotelianisms of the later middle ages and suggests that modern natural science may have identifiable origins prior to the Oxford Calculators or nominalists of the fourteenth century, and long before Kepler, Galileo or Newton.

From where does this emphasis on mathematics and the *experimentum* emerge? It has its conceptual origins in the Neoplatonic image of light as a 'formative power and form' of nature and a means of knowledge by illumination.[4] This Hellenistic tradition is the source of vivid light imagery deployed throughout early mediaeval Christian, Muslim and Jewish theology, for example in the works of St. Augustine, St. Basil, al-Farabi, Avicenna and Avicebron.[5] With scriptural precedent, light is associated with the life of God, emanation from divine being in the act of creation and the form of truth. Given that Grosseteste and Bacon were steeped in this tradition, particularly through the works of St. Augustine and the mystical theology of the Franciscans,[6] it is unsurprising to find

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larly enthusiastic appraisals of Roger Bacon as an experimental scientist, see, for example, the introduction to Robert Bridges' translation of Bacon's *Opus Majus: The Opus Majus of Roger Bacon*, 3 vols, London 1900; E. Charles, *Roger Bacon: Sa vie, ses ouvrages, ses doctrines*, Paris 1861, 102 ff.; C. Singer, *The Dark Ages and the Dawn*, in: F. S. Marvin (ed.), *Science and Civilization*, London 1923, 139-43; Joseph Kupfer, *The Father of Empiricism: Roger not Francis*, in: Vivarium, 22 (1974), 52-62; J. Hackett, *Roger Bacon on* Scientia Experimentalis, in: idem (ed.), *Roger Bacon and the Sciences: commemorative essays*, Leiden 1997, 277-315. For the view that Bacon is not a precursor of modern experimental science, see, for example, D. Lindberg, *Roger Bacon's Philosophy of Nature: A Critical Edition, with English Translation, Introduction, and Notes, of* De Multiplicatione Specierum *and* De speculis comburentibus, Oxford 1983, liii ff. and M. Heidegger (trans. W. Lovitt), *The Question Concerning Technology and other essays*, New York 1977, 122: 'If, now, Roger Bacon demands the *experimentum*—and he does demand it—he does not mean the experiment of science as research; rather he wants the *argumentum ex re* instead of the *argumentum ex verbo*, the careful observing of things themselves, i.e. Aristotelian *empeiria*, instead of the discussion of doctrines.' Bacon was deeply indebted to the work of Grosseteste who has himself been understood as a forerunner of modern experimental science. This view receives its most sustained defence in A. C. Crombie, *Robert Grosseteste and the Origins of Experimental Science 1100-1700*, Oxford 1953. Crombie's thesis has proved controversial and is discussed in detail below. For further comments, see, for example, A. Koyré, *The Origins of Modern Science: A New Interpretation*, in: Diogenes, 16 (1956), 1-22.

[4] See, for example, Pseudo-Dionysius, *De Divinis Nominibus*, IV.697c ff.; Plotinus, *Enneads*, I.6.3; III.8.5 and 11; IV.3.11; V.5.7; VI.7.41, *et passim*.

[5] See, for example, St. Augustine, *De Trinitate*, II.2, IV.27, VII.3 to 5, VIII.2 and 3, XII.15; St. Basil, *Hexaëmeron*, II.7 ff., VI, *et passim*. For a detailed description of Augustine's uses of light imagery, see F.-J. Thonnard, *La notion de lumière en philosophie augustinienne*, in: Recherches Augustiniennes, 1962, 124-75 and R. A. Markus, *Augustine: Reason and Illumination*, in: A. H. Armstrong (ed.), *The Cambridge History of Later Greek and Early Medieval Philosophy*, Cambridge 1970, 362-73.

[6] On the importance of light in Franciscan spiritual mysticism and its relationship to

light as a central and unifying theme in their writings on natural philosophy, metaphysics and theology.[7] An emphasis on the nature and meaning of light forges a bond between observation, natural philosophy, mathematics, metaphysics and theology for a number of reasons. Initially, four of these merit particular mention. First, light was implicated in many of the most fascinating and mysterious natural phenomena: the rainbow, the halo surrounding the atmosphere and light's presence in the uncorrupted and perfectly moving celestial bodies. Secondly, it is light itself which is the form of truth and which makes all things both visible and knowable.[8] Thus observation, the *experimentum*, is intimately linked to the attainment of truth through the mediation of light, both spiritual and visible. Thirdly, through a long tradition of investigation into the behaviour of light (*perspectiva*), exemplified in the works of Euclid and Ptolemy's treatises on optics, it was known that visible light acts according to the strict patterns of a yet more real and abstract mathematical geometry. In true Platonic fashion, mathematics could then mediate between the Supreme Light or Highest Truth, and the weaker light reflected in created nature which is nevertheless an emanation from that Highest Truth. At the beginning of his treatise *De Lineis, Angulis, et Figuris*, Grosseteste writes a much quoted exhortation to the use of mathematics in natural philosophy: "The usefulness of considering lines, angles and figures is the greatest, because it is impossible to understand natural philosophy without these."[9] Finally, and perhaps most importantly, the Christian scriptures describe God as light, and Christ as the light of the world.[10] On these grounds writers

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later natural philosophy, see R. French and A. Cunningham, *Before Science: The Invention of the Friars' Natural Philosophy*, Aldershot 1996, chs 9 and 10.

[7] For a general overview of light and its relation to metaphysics, see D. C. Lindberg, *The Genesis of Kepler's Theory of Light: Light Metaphysics from Plotinus and Kepler*, in: Osiris 2nd series (1986), 5-42.

[8] Robert Grosseteste, *De Veritate*, 137: "Veritas igitur etiam creata ostendit id, quod est, sed non in suo lumine, sed in luce veritatis summae, sicut color ostendit corpus, sed non nisi in luce superfusa. . . . Similiter potentia est lucis summae veritatis, quae sic illustrat veritatem creatam, quod ipsa etiam illustrata ostendit rem veram." Grosseteste's twenty-seven philosophical works, including *De Veritate* and *De Luce*, are available in *Die philosophischen Werke des Robert Grosseteste, Bischofs von Lincoln*, ed. L. Baur, Münster i. W., 1912 (available at http://www.grosseteste.com/). In references to *De Luce* and *De Veritate*, I follow the pagination of Baur's Latin text.

[9] Grosseteste, *De Lineis, Angulis et Figuris*, 59-60, ed. Baur (n. 8 above): "Utilitas considerationis linearum, angulorum et figurarum est maxima, quoniam impossibile est sciri naturalem philosophiam sine illis."

[10] For example, Genesis 1; Isaiah 60.19; John 1.1-18, 8.12 and 9.5; Acts 22.6f.; 1 Timothy 6.16; 1 John 1.5; Revelation 21.23; Revelation 22.5.

such as the Pseudo-Dionysius understood God to be the uncreated Light, and visible light to be God in action.[11] For Grosseteste, and later Bacon, to study light was to study God and all things in relation to God.

Focussing particularly on the thought of Robert Grosseteste and beginning with a brief exposition of his treatises *De Luce* and *De Veritate*, this article seeks to place the *experimentum* and use of mathematics in the wider context of his understanding of truth and illumination. Is mathematics merely a convenient language which encapsulates the natural? I will suggest that mathematics, for Grosseteste, draws together natural philosophy and metaphysics within a Platonic framework of participation in such a way that the fluctuations and vagaries of nature are not confined wholly within the strictures of mathematical formulae. Why was the *experimentum*, namely the observation of the motions of nature, suggested to Grosseteste? Against Alistair Crombie, the most vigorous defender of the view that Grosseteste's thought anticipates modern experimental science, I will argue that the practice of experimental observation is not introduced into natural philosophy to mitigate an inductive scepticism. Instead, it will be seen that, for Grosseteste, there could never be a 'problem of induction' as there was for the early modern scientists.[12] Because of his Neoplatonic understanding of truth in which all things are ultimately illuminated in the eternal light of the Trinity, there is no dark, unilluminated logical gap between the observation of singulars and the postulation of universal first principles of nature which must be traversed by a baseless inductive intuition. Rather, for Grosseteste, the *experimentum* is of theological importance: it may help us to assuage the effects of the Fall on human knowledge. Crucially, it will be seen that divine illumination is not something added to the kind of inductive reasoning associated with the systematic, experimental observation of nature; rather, both belong to a single, divine guarantee of truth. Whereas our contemporary discussions of science and religion seek to reconcile apparently conflicting authorities

[11] See Pseudo-Dionysius, *The Divine Names*, 693b ff.

[12] The 'problem of induction', classically stated by David Hume (see his *Enquiry Concerning Human Understanding*, IV.2), concerns the legitimacy of the inference of universals from particulars. For example, is it rational to infer from a single observation that A causes B, that this is universally the case, particularly given that, as Hume stated, one only observes the conjunction of events and not actual causal processes? Moreover, is it rational to assume that nature will behave in the same way in the future as it has in the past? Science appears to assume an affirmative answer to both questions. The practice of the constantly repeatable experiment, in which particular instances of causal connections are observed over and over, seems to be an attempt to assuage an apparent *aporia*. The problem of induction will be discussed further below, pp. XXX.

and epistemologies—religion is founded in narrative, tradition and communally authoritative texts, whereas science is founded on supposed observational facts and syllogistic deduction—in the work of Grosseteste one finds natural philosophy and theology lying under a single, transcendent truth. Finally, I will suggest that Grosseteste's thought remains interesting not because he is a proto-modern experimental scientist, but for a much more suggestive reason: he offers a view of the sciences as distinct but unified in their participation in the one divine and transcendent light. I begin, however, with the broader and crucial context of Grosseteste's thought, namely his cosmogony of light.

A Cosmogony of Light

How does Grosseteste understand the nature of light, and what is light's place in his cosmogony? "The first corporeal form", writes Grosseteste at the very beginning of his treatise *De Luce*, "which some call corporeity is in my opinion light."[13] Of its own accord, light spreads itself instantly from a single point in every direction (unless obstructed) and so forms a sphere. Light is dynamic and possesses an instantaneous self-motion and self-propagation.[14] Continuing with a consideration of the nature of corporeity and matter, Grosseteste presents two propositions: corporeity is that which necessarily accompanies the extension of matter into three dimensions, yet *in themselves* matter and corporeity are simple substances lacking dimension. However, a consideration of matter on its own could only be conceptual: it cannot be separate from form, and the form of matter we observe in the universe is diffusion into three dimensions. That which, of its own accord, diffuses itself in this fashion is light. Therefore, concludes Grosseteste, light is the first bodily form, which some call corporeity; it necessarily accompanies and enables the diffusion of matter into three dimensions.[15] Because it is the first bodily form, light is therefore the most noble and comparable to forms which exist separately such

[13] Grosseteste, *De Luce*, 51: "Formam primam corporalem, quam quidam corporeitatem vocant, lucem esse arbitror." Marking the importance of Grosseteste's *De Luce*, McEvoy comments that this work is 'one of the few scientific cosmologies, and perhaps the only scientific cosmogony, written between the *Timaeus* and modern times.' (J. McEvoy, *The Philosophy of Robert Grosseteste*, Oxford 1982, 151).

[14] This is not, according to Grosseteste, a local motion, for if it were we would perceive illumination to occur in stages. See Grosseteste, *Hexaëmeron*, II.10.1.

[15] See Grosseteste, *De Luce*, 52: "Lux ergo, quae est prima forma in materia prima creata, seipsam per seipsam undique infinities multiplicans et in omnem partem aequaliter

as intelligences. Within the cosmological hierarchy, light as the first corporeal form stands at the hinge between the physical and separate substances, sharing more intensely in the nobility and greater being of the higher realms. Through the mediation of light as its first form, matter is thereby exalted to share in a greater being.

Having outlined the primacy and excellence of light, Grosseteste deploys the mathematics of relative infinities to explain the finite extension of the universe from a simple point. How could a finite corporeal universe emerge from a simple point lacking dimension, namely the point of light? Referring to the authority of Aristotle, Grosseteste states that the 'quantity' of the cosmos could not be the result of a merely finite multiplication of a simple thing such as light because the *ratio* between something simple and something finite is itself infinite.[16] Therefore, because a finite thing exceeds a simple thing infinitely, the primordial light must be multiplied an infinity of times in order to extend matter and produce a finite corporeal universe.

However, does this mean that the cosmos will be one spatially homogenous and undifferentiated mass? No, because the infinities by which light is multiplied may vary. For example, Grosseteste states that the sum of all numbers is infinite and yet is greater than the sum of all even numbers even though this latter is also infinite. Importantly, there can be proportions between infinities: the sum of numbers doubled from one to infinity is an infinite, as is the sum of half of all these doubled numbers, yet "the sum of these halves must of necessity be half the sum of their doubles."[17]

From these propositions concerning the mathematical proportions of various infinities, Grosseteste claims that light extends matter into larger or smaller dimensions according to the proportionate infinities by which it is multiplied,

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porrigens, materiam, quam relinquere non potuit, secum distrahens in tantam molem, quanta est mundi machina, in principio temporis extendebat."

[16] It is not clear to which of Aristotle's texts Grosseteste is referring. McEvoy suggests *De Caelo*, I.5.271b15 ff. (McEvoy 1982 (n. 13), 152).

[17] Grosseteste, *De Luce*, 53: "Quorum subduplorum aggregationem necesse est esse subduplam ad aggregationem duplorum suorum." Grosseteste's final proposition relating to infinities is that the infinite sum of all doubled numbers is not related by a rational proportion to the infinite sum of corresponding halves from which has been subtracted a finite number (for example, 1). The proportion which remains will only be expressible as an irrational number.

> for if light through the infinite multiplication of itself extends matter into a dimension of two cubits, by the doubling of this same infinite multiplication it extends it into a dimension of four cubits . . .[18]

Thus the extension of matter in increasing sparsity through the universe is explained by the mathematics of different infinities by which the point of primordial light may propagate itself.

It is possible to see in this section of *De Luce* a Platonic understanding of mathematics. Grosseteste begins with a primordial light which is wholly single and one. Considered mathematically, unity or the one is not the first number, but the principle of all number. Multiple entities participate in unity, for they are multiplications of a unity which is their conceptual and ontological basis. In an analogous fashion, light, as the first bodily form, is not merely the first body: it is the basis, conceptual and ontological, of all material extension. This material extension into multiple proportions participates in the single unity of the first bodily form which is light. This is to say that the advent of the material realm which is Grosseteste's subject matter in *De Luce* is a participation in the mathematics of the one and the many, where mathematics forms a mediatory bridge between metaphysics, which is concerned with the higher being of unchanging simplicity (into which would fall *lux*), and physics which is concerned with the multiplicity of differentiated, complex, moving beings in the cosmos (into which would fall *lumen*). The one and the many, *lux* and *lumen*, are not in dualistic opposition: the latter participates in the former.[19]

Having outlined in more detail a cosmogony of light, describing the hierarchical structure of the heavens, the formation of the elements through the various rarefactions of matter and deriving the different motions of

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[18] Ibid.: 'Si enim lux multiplicatione sui infinita extendit materiam in dimensionem bicubitam, eadem infinita multiplicatione duplicata extendit eam in dimensionem tetracubitam . . .' As an aside, Grosseteste remarks that this principle was well known to both Atomists and Platonists. The former understood all things to be composed of atomic units, while the latter believed all things to be composed of surfaces, lines and points.

[19] See Plato, *Republic*, 524a ff. Grosseteste's line of thought may have interesting origins in Pythagorean science. Of the Pythagoreans, Jacob Klein comments that, 'We may conjecture that they [Pythagoreans] saw the genesis of the world as a progressive *partitioning* of the first 'whole' *one*, about whose origins they themselves, it seems, were not able to say anything conclusive . . . This first 'one', as well as the subsequent 'ones' which were the result of partition, i.e., the 'numbers' themselves, they therefore regarded as having *bodily extension* . . .' in: *Greek Mathematical Thought and the Origin of Algebra*, Cambridge, Massachusetts 1968, 67.

the cosmos, Grosseteste concludes his treatise by adducing the unity of the cosmos through certain mathematical proportions. These are, once again, characteristically Platonic and reminiscent of the cosmology of the *Timaeus*. The highest body contains four constituent parts: form, matter, composition and the composite. In other words, the form, being totally simple and devoid of composition, is akin to mathematical unity. By contrast to this fundamental unity, matter constitutes the dyad on account of a two-fold potency: a receptivity to impressions received from without and divisibility. However, there is also composition, this being akin to the number three, for in composition we find informed matter, materialized form and the order between these two. Finally, the quaternary is the composite proper, over and above these three constituents.[20] The cosmos therefore constitutes a unity because it possesses all these principles which together are sufficient and necessary for completeness:

> something . . . corresponding to form and unity, and something corresponding to matter and duality, something corresponding to composition and trinity, and something corresponding to the composite and quaternity.[21]

There is a fundamental unity in the multiplicity of being within the cosmos, seen most particularly in the multiplicity of motions which emerge from the simple circular motion of the first heaven. Moreover, this whole is one of five harmonious proportions found in the first four numbers (the numbers themselves plus the whole which they constitute), these producing harmony in "musical melodies, in bodily movements, and in rhythmic measures."[22]

Thus Grosseteste is able to formulate a cosmogony based on light with mathematics providing not just a conceptual hinge between metaphysics and cosmology, but also the ontological mediation between the simple, motionless singularity of the first bodily form and the moving multiplicity of an extended, material creation. Mathematics is more than a convenient language for describing the cosmos, because number is integral to the being of the materially extended, moving and harmonically unified creation.

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[20] Grosseteste, *De Luce*, 58.

[21] Ibid.: "Ex his patet, quod denarius sit numerus universitatis perfectus, quia omne totum et perfectum aliquid habet in se sicut formam et unitatem, et aliquid sicut materiam et binarium, et aliquid sicut compositionem et ternarium, et aliquid sicut compositum et quaternarium."

[22] Ibid.: ". . . in musicis modulationibus, gesticulationibus et rythmicis temporibus."

It is clear from other writings, however, that for Grosseteste light does not merely relate to the first corporeal form or to visible light in creation, but supremely to God himself. In his *Hexaëmeron*, a meditation on the six days of creation, Grosseteste relates light analogically to the life of the Trinity in a fashion reminiscent of the Neoplatonic emanationist doctrine of creation. He writes that,

> From the fact that God is a Trinity of persons, it follows that God is light: not bodily light but non-bodily light. Or rather . . . beyond either. Every light has by nature and essence this characteristic, that it begets splendour from itself. The light that begets and the splendour that is begotten necessarily are locked in a mutual embrace, and breathe out their mutual warmth.[23]

Thus his cosmology and cosmogony are linked with the doctrine of God through analogical participation in the supreme light of the Trinity.

However, is Grosseteste's deployment of light in describing the life of God and the formation and motions of the cosmos merely a convenient metaphor? Or is light the basis of a wider metaphysics which also encompasses a theological understanding of truth and science? To answer these questions, I turn initially to the treatise *De Veritate*, before considering Grosseteste's commentary on Aristotle's *Posterior Analytics* and his advocacy of the *experimentum*.

Light and Truth

Grosseteste begins *De Veritate* with no less than seven arguments in favour of the proposition that there is a truth other than the supreme truth. Having adduced five arguments to the contrary, he marshals the authority of St. Augustine in postulating that everything which is known to be true is observed to be true in the light of the supreme truth.[24] However, does the light of this supreme truth obliterate all other truth, just as the light of the sun is able to wipe out the power of other illuminaries? Just

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[23] R. Grosseteste, *Hexaëmeron*, VIII.3.1, ed. R. C. Dale and S. Gieben, London 1982, 220, 1-6: "Quod autem Deus sit in personis trinus, inde sequitur quod Deus est lux, non corporea sed incorporea; immo magis neque corporea neque incorporea, sed supra utrumque. Omnis autem lux hoc habet naturaliter et essencialiter quod de gignit suum splendorem. Lux autem gignens et splendor genitus necessario sese amplectuntur mutuo, et spirant de se mutuum fervorem." Unless otherwise indicated, all translations are from R. Grosseteste, *Hexaëmeron*, (On the Six Days of Creation), trans. C. F. J. Martin, Oxford 1996.

[24] Grosseteste, *De Veritate*, 137: "Verum est igitur, sicut testatur Augustinus, quod nulla conspicitur veritas nisi in luce summae veritatis."

as in the case of *De Luce*, Grosseteste is posing the problem of unity and multiplicity: how is the unity of the supreme truth related to the possibility of genuinely other, multiple truth? In order to answer this question, Grosseteste first enquires into the nature of truth.

Immediately, Grosseteste outlines truth as inhering in the eternal speech of God. Rather than being a mere adequation of speech and thing, truth is found fundamentally and eternally in the 'interior' speech of God, namely the emanation of the Son from the Father.[25] Not only is the speech of the Father adequated in the highest manner to the thing of which it speaks, it is that very adequation of itself to the thing it states. This speech forms the 'exemplars' of all things in such a way that "the conformity of things to this eternal speaking is the rightness of them and the obligation to be what they are."[26] For Grosseteste, following the tradition of the convertibility of the transcendentals, truth, goodness and being are convertible in that something is true in so far as it is what it should be according to its idea in the divine mind which emanates from the divine being in the eternal speech of the Father.[27] Grosseteste claims,

> A tree is a true tree when it has the plenitude of being tree and lacks the deficiency of being tree, and what is this plenitude of being except conformity to the reason of tree in the eternal Word?[28]

If truth consists in the conformity of each thing to its reason or idea in the eternal Word, this implies that in order to obtain truth one must be able to observe both the created object *and* its eternal exemplar. For Grosseteste, therefore, created truth is attainable in so far as the light of eternal reason is present to the person observing.[29] Therefore, created truth is attained in so far as the light (*lux*) of the divine reason is present to the observer. Just as a body cannot be seen to be coloured with-

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[25] Ibid., 134. Aquinas was later to adopt a very similar approach to truth. Grosseteste here prioritises 'interior' speech over verbal speech because he understands truth to be predicated on a hierarchy of emanation in which a more immanent emanation implies a more replete and complete communication of being.

[26] Ibid., 135: "Ipsa quoque conformitas rerum ad hanc aeternam dictionem est earum rectitudo et debitum essendi quod sunt."

[27] Ibid.: "Sed inquantum est res ut debet, intantum vera est. Igitur veritas rerum est earum esse prout debent esse, et earum rectitudo et conformitas Verbo, quo aeternaliter dicuntur."

[28] Ibid.: ". . . tunc enim est vera arbor, cum habet plenitudinem esse arboris caretque defectione esse arboris, et haec plenitudo essendi quid est nisi conformitas rationi arboris in Verbo aeterno?"

[29] Ibid., 137.

out the presence of an extrinsic light, so too something cannot be known within its created truth alone.

At this point in his treatise, Grosseteste makes a subtle alteration to a basic simile concerning knowledge and illumination in order to show how created truth is not rendered redundant by divine illumination, but is instead made possible by a participation in eternal truth.[30] The familiar simile likens the divine light to the light of the sun which makes created objects visible. However, the sun obliterates and renders invisible all other sources of illumination. Grosseteste claims that a more appropriate comparison might be drawn. The highest, eternal truth is not to the other created truths as the sun is to other luminaries in the sky. Rather, the highest truth is to created truth as the sun is to colour. The sun illuminates colour which, by 'participating' in this light, reveals the body. Importantly, it is not a deficiency of the light of the sun which makes colour necessary to the illumination of a body, but a hierarchy of illumination ensures that created bodies are drawn to reveal themselves: the sun draws the colour to be colour and reveal itself as such, while the colour in turn, because it is integral to the being of the body and not a mere 'secondary quality', reveals that body as, say, a strawberry. While it is true that no truth is perceived except in the light of the supreme truth, nevertheless created being participates in this truth and therefore is said to reveal itself in a secondary but real sense. This is reminiscent of a particularly Neoplatonic account of causation: the created light is the secondary but immediate 'cause' of created truth, while the supreme light is the primary and most potent 'cause' of truth, being and goodness.[31] Meanwhile, a final addition to this simile of the supreme truth and the sun brings further clarity to Grosseteste's notion of truth. Just as the weak eye is not able to see colour except in the light of the sun, but cannot look directly upon the sun, so the created mind can only see created truth in the light of the supreme truth, but cannot look directly upon the light of the supreme truth. The supreme truth is always mediated to created being.

This familiar and Platonic simile of the vision of the sun and the vision of the supreme truth allows Grosseteste to make a brief speculation on the relationship between the knowledge and truth attainable by the 'impure'

[30] Ibid., 137-8.

[31] See Aquinas, *Super Librum De Causis Expositio*, proposition 1.

and the knowledge and truth attainable by the 'pure in heart'.[32] This distinction, expressed here in terms of the *immundi* and *mundicordes*, might also be the distinction between pagan philosophy and the truth which can be seen in the light of Christian revelation. However, it is clear from Grosseteste's writing that pagan learning (by which we may assume that he is thinking particularly of the newly circulated writings of Aristotle upon which Grosseteste will later compose commentaries) has a measure of truth, albeit thoroughly mediated through reflection in created being, that is, at one remove from the truly real. And yet, of course, this 'one remove' is by no means off the mark: there is no one who knows any truth, who does not also know in some manner, knowingly or ignorantly, the supreme truth itself.[33] The pagan learning of the philosophers has its own value and is, in a more indirect fashion, a knowledge of the supreme truth. However, there is a genuine difference between the illumination attained by Christian revelation and that attained by pagan learning. It is a difference which is in turn based upon an ontological difference between the light of the supreme truth (*lux*), which is eternal, unitary and simple, and that light reflected in creatures (*lumen*) which is created, multiple and thereby less certain. The light of the supreme truth is different from the created light, and yet the latter is not autonomous; it is dependent upon the former.[34] In a similar fashion, for Grosseteste, it appears that the sciences other than Christian theology are *different*, but not understood as *autonomous*, any more than created being is autonomous from the supreme truth, or *lumen* from *lux*.

A crucial issue now arises which relates to human knowing. To what extent is Grosseteste advocating what was later to be termed 'ontologism', namely, the view that the mind directly intuits knowledge of God in all its acts of knowledge, before reaching heaven? In other words, is human knowledge the result of a direct illumination of the human intellective soul by the light of the divine? If this were the case, knowledge would be akin to God's timeless knowledge because we would have a vision of the eternal and unchanging divine ideas themselves. Or, is motion an integral part of the attainment of truth for Grosseteste, in which we come

[32] Grosseteste, *De Veritate*, 138. This issue receives greater attention in Grosseteste's *Commentarius in Posteriorum Analyticorum Libros*. For a discussion of this matter in the Commentary see McEvoy 1982 (n. 13), 323 and 332-4.

[33] Ibid.

[34] This we learn from Grosseteste when he likens the dependence of created being on God's eternal Word to the dependence of water on its container for its support and form. *De Veritate*, 141-2.

to knowledge in mediated form through time? In what follows, I will argue that Grosseteste does not rule out intuited knowledge of God even within the temporal life, yet he acknowledges that, because of our weakened post-lapsarian state, we require motion and time in order to come to truth, and this necessitates the observation of corporeal being which eventually suggests the importance of the repeated observations of an *experimentum*.

Illumination, the Senses and the Motion of Knowing

In his discussion of Grosseteste's understanding of truth, James McEvoy is anxious to exonerate his subject of the charge of ontologism because this theory of illumination renders the difference between the knowledge attained by the blessed and the knowledge attained by the *viatores* 'a matter merely of degree'.[35] With reference to the *Commentary on the Celestial Hierarchy*, McEvoy outlines Grosseteste's belief that the direct intuition of God in this life has been attained by only a very few privileged mystics (for example, Moses and St. Paul[36]) who may then be referred to as the *mundicordes* or *perfecte purgati*. This is a momentary and anticipatory sharing in the beatific vision. By contrast, knowledge that we ordinarily attain, whether of God or creatures, is of a different order. Thus the attainment of truth is understood as a hierarchy extending from the weakness of prescientific opinion to the direct vision of God. How might we identify more precisely the difference between knowledge attained through the mediation of created light and the knowledge of the blessed in the direct vision of God? To answer this question, it is necessary first to consider Grosseteste's understanding of universals before progressing to the importance of sensation and their link with the hierarchy of the elements.

In his commentary on Aristotle's *Posterior Analytics*, Grosseteste makes a distinction between four kinds of universal.[37] The first kind are the ideas

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[35] McEvoy 1982 (n. 13), 326. For McEvoy's full discussion of Grosseteste and the charge of ontologism, see 324 ff. While concurring with much of McEvoy's discussion, it will be evident from what follows that I avoid his description of Grosseteste's theory as 'dualistic' (328). It seems that the whole thrust of Grosseteste's *De Veritate* is towards the delineation of an account of truth which recognises multiplicity and difference without juxtaposing this with the simplicity of the divine *lux* in any proto-modern, dualistic fashion.

[36] See, for example, Grosseteste, *Hexaëmeron*, I.6.1.

[37] Grosseteste, *Commentarius in Posteriorum Analyticorum Libros*, I.7, 96 ff., ed. P. Rossi, Firenze 1981, 139-41. Hereafter, this work is cited as 'Grosseteste, *Commentarius*'. See also P. Duhem, *Le Système du Monde: histoires de doctrines cosmologiques de Platon à Copernic*, vol. V, Paris 1958, 345-51; McEvoy 1982 (n. 13), 327-9; S. Marrone, *William of Auvergne and Robert Grosseteste: New Ideas of Truth in the Early Thirteenth Century*, Princeton 1983, 167-71.

in the mind of God which are contemplated in the supreme light by intellects separated from phantasms. These are the principles of knowledge and being. The second kind of universal resides in the angelic *intelligentia* or *lux creata* whose knowledge of all subsequent creatures is derived from a prior and direct contemplation of the divine ideas. These universals exist within the thought of the *intelligentia*; illumination of the human mind, which is not able to contemplate immediately the supreme light, comes from the light of this *intelligentia*. The third variety of universal resides in the celestial bodies. A mind which is not capable of the contemplation of the supreme light or the angelic *lux creata* may find in the light of the celestial bodies the principles of the sublunary realm which is subject to motion. The fourth variety of universal is to be found in form which, in its turn, is able to illuminate the material in which it resides and with which it constitutes a composite. It is here that one might find the immediate formal cause of things and their universal principles. Finally, in addition to the four varieties of universal, Grosseteste comments on the very lowest form of 'knowledge' (more properly termed 'opinion') attainable by the *intellectus debilis*. The 'knowledge' attained here does not concentrate upon universals at all, but is arrived at through the observation of accidents.[38] The link between knowledge and being is undone in such a way that the principles of this 'knowledge' are merely the accidents of things and not their essence (*principia essendi*). Such 'knowledge' is thereby wholly uncertain and might be more properly termed 'opinion'.

Throughout this hierarchy of universals, the latter are dependent on the former, and each mediates light to the lower levels of created being. This is a hierarchy of knowledge attainable by human beings which is also a hierarchy of being. In extending Grosseteste's immediate descriptive terms we might also understand this in terms of a hierarchy of the 'motion' or 'change' that is involved in the attainment of truth. At the highest level of contemplation—which is the beatific vision and the highest level of knowledge—we find the universals in the actuality of the eternal emanation of the Word of God. The contemplation of these universals or 'divine ideas', which the blessed share with the angelic *intelligentia*, takes the form of immediate intuition. This might even be understood as akin to Aristotelian *energeia*: this knowledge is fully actual and 'all at once', being replete and contained within its own limits for it seeks nothing

[38] Grosseteste, *Commentarius*, I.7, 141 ff.

beyond itself.[39] The principles of this knowledge are 'the uncreated reasons of things'[40] and the pure and intuitive intellect can grasp these with complete certainty without the mediation of time. The next level of contemplation is through (rather than with) the angelic *intelligentia*. This *lux creata* is a reflection of the supreme light of the divine mind, yet it contains within itself the first intimations of motion proper, for this knowledge is not necessary and has proceeded into being. Moreover, we learn from *De Luce* that the *intelligentia*, which is the first reflection of the supreme light, is the incorporeal moving power which moves the celestial spheres with a diurnal motion.[41] So at the next level of the universal we find the celestial spheres which contain within themselves the light or principles of everything that occurs below within the cosmic hierarchy. These bodies possess a diurnal rotation which is a motion most akin to the created actuality of the angelic *intelligentia* and the truth of the supreme light. Why? Because this diurnal rotation can be regarded as the most complete and self-contained local motion for, unlike rectilinear motion, it does not seek an end outside its own self-delineated limits. Finally, the universals of the celestial sphere impart motion to the lowest level of universal, namely the forms of created beings. This final motion may be rectilinear to a greater or lesser extent depending on a created being's particular susceptibility to condensation and rarefaction.[42]

In addition to this hierarchy of universals and motion, there is also an important hierarchy of the elements and the senses. The cosmic hierarchy of elements begins at its height with the serenity of the heavens and the light of the 'fire' of the celestial bodies, and descends through the air to water and earth.[43] Coupled to the elements is the hierarchy of sense.

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[39] At *Metaphysics* IX.5-6 ff., Aristotle draws a distinction between *energeia* (actuality or operation, which is not orientated to an extrinsic *telos*) and *kinesis* (motion, which has a *telos* outside itself). For detailed discussions of this distinction see, for example, J. L. Ackrill, *Aristotle's Distinction Between* Energeia *and* Kinesis, in: R. Bamborough (ed.), *New Essays in Plato and Aristotle*, London 1965, 121-41; S. Menn, *The Origin of Aristotle's Concept of* Energeia: Energeia *and* Dunamis, in: Ancient Philosophy, 14 (1994), 73-114; D. Graham, *The Development of Aristotle's Concept of Actuality: Comments on a Reconstruction by Stephen Menn*, in: Ancient Philosophy, 15 (1995), 551-64; and G. A. Blair, *Unfortunately, It Is a Bit More Complex: Reflections on* Energeia, in: Ancient Philosophy, 15 (1995), 565-80.

[40] Grosseteste, *Commentarius*, I.7, 102-3.

[41] Grosseteste, *De Luce*, 57: "Quapropter virtus incorporalis intelligentiae vel animae, quae movet sphaeram primam et supremam motu diurno, movet omnes sphaeras caelestes inferiores eodem diurno motu."

[42] See ibid., 57-8.

[43] Grosseteste, *Hexaëmeron*, VI.1.1-3.

Grosseteste quotes Augustine to the effect that in sensation we do not find simply the action of an object on the passive senses of a subject. The encounter between a sentient creature and the creature which is perceived is one in which the action of one upon the other is reciprocal. The sensitive soul, we are told,

> *acts* in the eyes through the pure shining fire "when its heat is suppressed and made into its pure light. But in hearing the fire penetrates by its heat into the more liquid air. In smell the pure air comes through and reaches the moist exhalation . . . In taste it comes through and reaches the moisture that is more bodily: and it goes into this and through this when it reaches the heaviness of the earth, and makes the last sense, that of touch."[44]

Whereas this passage puts forward the notion that the sensitive soul acts through the senses on the bodies sensed, elsewhere Grosseteste outlines what was later to be known as the doctrine of 'the multiplication of species': everything in the sublunary world acts on its surroundings through an emanation of a likeness of itself.[45] Grosseteste states that

> A natural agent multiplies its power from itself to the recipient, whether it acts on sense or matter . . . But the effects are diversified by the diversity of the recipient. For when its power is received by the senses, it produces an effect that is somehow spiritual and noble; by contrast, when it is received by matter, it produces a material effect.[46]

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[44] Ibid., VI.1.3, quoting Augustine, *De Genesi ad litteram*, III.5-6: "Agit enim anima sentiens in oculis per ignum lucidum 'represso calore eius usque ad lucem eius puram. In audito vero usque ad liquidiorem aerem, calore ignis penetrat. In olfactu autem transit aerem purum et pervenit usque ad humidam exalacionem . . . In gustu autem et hanc transit et pervenit usque ad humorem corpulentiorem; quo eciam penetrato atque transiecto, cum ad terram gravitatem pervenit, tangendi ultimum sensum agit.' " More particularly, Grosseteste held to the extramission theory of vision propounded by Plato, Aristotle, Ptolemy and Euclid. On this view, the act of vision includes rays pouring forth from the eye. See Grosseteste, *Commentarius*, II.4, 464 ff.; *De Iride*, 72-3, cited in Crombie 1953 (n. 3), 118. As Crombie states, the thirteenth century saw considerable debate about whether the multiplication of light is a real movement in space or merely the result of perception. Roger Bacon (c. 1220-c. 1292) appears to opt for the former explanation, adding that light passes in an imperceptible time, and therefore with a motion we cannot perceive (*The Opus Majus of Roger Bacon*, ed. and trans. Robert Belle Burke, Philadelphia 1928, Part V, distinction 9, chapter 3, 488 ff.).

[45] On this doctrine, which received more comprehensive enunciation in the work of Roger Bacon, see Lindberg 1983 (n. 3). Lindberg remarks that this doctrine has its origins in the work of Arabic philosophy, in particular al-Kindī (lii).

[46] Grosseteste, *De lineis, angulis, et figures*, 60; cited in Lindberg 1983 (n. 3), lii: "Agens naturale multiplicat virtutem suam a se usque in patiens, sive agat in sensum, sive in materiam . . . Sed propter diversitatem patientis diversificantur effectus. In sensu enim ista virtus recepta facit operationem spiritualem quodammodo et nobiliorem; in contrario, sive in materia, facit operationem materialem . . ."

Within this exchange between sentient creature and that which is sensed, one finds fidelity to the principle that 'like knows like': sight perceives 'fire' or the rarefied *lumen*, hearing perceives the relatively rarefied air, smell perceives the thicker air, taste perceives liquid or water, and touch perceives earth. However, as we might expect, all sensation is linked analogically to light, for 'light is the instrument of the soul in sensing through the senses of the body.'[47] Again, Augustine is quoted to the effect that light is that by which the soul acts in all the senses. Thus sensation is integrated into a general light metaphysics, for just as each of the elements is a more or less dense form of light, so too the sensitive souls of animals in their activity of sensing use a form of light which is akin to the element which is being sensed. Both the sentient creature and that which is perceived by the senses are constituted and related in the activity of light. Moreover, this emanation of species from all things, in being a form of light, acts in accordance with the principles of geometrical mathematics. Thus Grosseteste can claim that all causes of natural effects can be discovered by lines, angles and figures.[48]

However, it is important to note that, just as the lower universals are analogously related to the higher by participation, so too are the senses. For Grosseteste, the lowest sense is that of touch because this is concerned with inert earth which, amongst the elements, is the most dense and least actual form of light. The sense of touch is analogously related to taste, then smell, hearing and finally sight. Yet sight itself, the highest of the bodily senses, is analogously related to the vision of the inner mind possessed by those who contemplate the angelic *lux creata* and the divine light itself. At the highest level of knowledge and 'sight' in the beatific vision, we 'see' the light of the supreme truth with the purified and unencumbered eye of the mind. This vision of God is the culmination by grace of the restoration of humanity in the image and likeness of God.[49] Because this knowledge is fully replete, actual and unmediated, it involves no motion or temporality. This beatific vision is an activity of the soul which no longer requires the mediations of bodily sensation.

A link is established between, on the one hand, the universals and motion, and, on the other hand, the elements and the senses. Before coming to a conclusion about how we might draw a distinction between

[47] Grosseteste, *Hexaëmeron*, II.10.1.
[48] See n. 9 above.
[49] See McEvoy 1982 (n. 13), 94 n. 73.

knowledge attained through the mediation of created light and knowledge in the beatific vision, it is first necessary to clarify briefly one more connection between motion and the particular knowledge achieved by corporeal sensation. Initially, one can note that sensation is the result of the motion of the species or likeness of a creature to reside in the sensitive soul of an animal. Sensation is, therefore, already a kind of abstraction, because "the outward sense is a power of receiving and grasping sensible species without matter."[50] The various species which arrive in the sense organs are then collated in the 'common sense' (*sensus communis*) to form a less fragmented and more integrated sense impression. From here, the united 'likenesses' of the perceived object are passed into the memory. Properly speaking, it is the imagination which retains the forms which have been sensed, while the memory proper includes the estimative power of judging the forms received. The motions from the senses to the memory are shared by all rational animals. The final motion involves the excitement of reason by many memories that are held in the soul. These motions involved in sensing are described in the final chapter of Grosseteste's commentary on the Aristotle's *Posterior Analytics*:

> In those who have this sense as well as retention, there is a gathering of one memory from many sensations and this is common to brute animals and rational beings; but in rational beings it is already the case that from many memories, once reason is excited, an experience is formed; this is not the case with non-rational animals. Therefore, from sense comes memory, from the repetition of many memories an *experimentum* and from the *experimentum* the universal which is apart from the particulars, yet not separate from the particulars but the same as them, namely as the principle of both art and science.[51]

This whole systematic procedure of sensation, which is already a form of abstraction made possible by the emanation of species due to the dynamism of light which constitutes the more or less rarefied sensible elements of fire, air, water and earth, was to yield universal principles of nature, what Grosseteste called *universalia complexa experimentalia*, 'complex experimental universals'.

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[50] Grosseteste, *Hexaëmeron*, VII.14.1: "Est autem exterior vis susceptiva et apprehensiva sensibilium specierum sine materia."

[51] Grosseteste, *Commentarius*, II.6, 33-40: "In quibus autem est sensus cum hac retentiva, est colligere ex multis sensibus unam memoriam, et hoc commune est brutis cum rationalibus; sed in rationalibus iam contingit ex multis memoriis excitata ratione fieri experientiam; in brutis vero non est hoc. Ex sensu igitur fit memoria, ex memoria multiplicata experimentum, ex experimento universale, quod est preter particularia, non tamen separatum a particularibus, sed est idem illis, artis, scilicet, et scientie principium."

The hierarchies of universals, elements and sensations in which the higher mediate light to the lower also feature ever more perfect motions as one ascends towards the supreme light which is the source of all goodness, being, truth and knowledge. The distinction between the knowledge attained in the mediation of the created light and that attained in the beatific vision might therefore be made in terms of motion. The latter features an immediate and intuitive grasp of truth which requires no movement or change. As was claimed above, we might even consider this akin to Aristotelian *energeia*, for this knowledge is replete and not mediated by time. Yet as a result of the Fall, we do not share in the beatific vision. The sin which results from the Fall is understood as a disordered desire in which the human soul seeks first after corporeal things rather than the higher light of God himself. Grosseteste argues that if the intelligence were not weighed down by the body it would receive complete irradiation, and therefore knowledge and fully actual being, from the supreme light. Because this purity is obscured by corrupt desires,

> all the powers of this rational soul born in man are laid hold of by the mass of the body and cannot act and so in a way are asleep. Accordingly, when *in the process of time* the senses act through many interactions of sense with sensible things, the reasoning is awakened and mixed with these very sensible things and is taken in the senses to sensible things as in a ship.[52]

Therefore, in a fashion strikingly reminiscent of the Platonic doctrine of recollection, Grosseteste states that our souls require awakening by the repeated 'motions' in time of our corporeal senses. Within this context, the order of being and intelligibility is the reverse of *our* order of knowing, for fallen humanity must begin with knowledge of the less intelligible created and corporeal being by means of the motions of sensation before achieving the vision of the supremely intelligible light of the divine ideas.[53] Thus the lower one descends towards corporeal sensation, the greater the temporality or motion involved in knowing. Is there, then, a dualism between the knowledge attained in the beatific vision and that attained by fallen humanity? Just as there is no dualism between Platonic being and becoming and Aristotelian *energeia* and *kinesis*, so too there is

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[52] Ibid., I.14, 235-41, (my emphasis), quoted in Crombie 1953 (n. 3), 73: ". . . omnes vires ipsius anime rationalis in homine nato occupate sunt per molem corporis, ne possint agere, et ita quodammodo sopite. Cum itaque processu temporis agant sensus per multiplicem obviationem sensus cum sensibilibus, expergiscitur ratio ipsis sensibus admixta et in sensibus quasi in navi delata ad sensibilia."

[53] Ibid., I.17, 340-65.

no dualism between Grosseteste's beatific vision and the knowledge that is attainable in this life, because amidst all these distinctions the former participate in the latter. In the case of Grosseteste, all levels of knowledge are analogically related in light. Yet distinctions can be made between the different sciences which deliver different kinds of knowledge, and these distinctions may be delineated by the need to be awakened from potency to act.

In Grosseteste's commentary on Aristotle's *Posterior Analytics*, directly after his description of the need for sensation to awaken the soul to the light of truth, the author describes what many commentators cite as the description of a an experimental procedure. Having descended from the supreme light of God to consider the place of corporeal sensation in Grosseteste's metaphysics, we now turn to examine in greater detail the place of the *experimentum* in the methodology of his natural philosophy.

The Experimentum

Commenting on Aristotle's methodology in natural science, Grosseteste describes how scientific reasoning is found in the syllogistic demonstration of the links between causes and effects, premises and conclusions. There is a distinction between, on the one hand, the knowledge of facts ('that' or *quia*), and, on the other hand, knowledge of the cause or reason for the fact ('why' or *propter quid*). There is therefore a distinction between science which accumulates facts (*scientia quia*) and that which is more properly called 'science' and gives a more genuine knowledge, namely the enquiry which seeks explanation and demonstration with respect to causes (*scientia propter quid*), those causes being the four Aristotelian varieties. As Crombie indicates,[54] Aristotle uses the following syllogism as an example of *scientia quia*: what does not twinkle is near, planets do not twinkle, therefore they are near. This does not produce the reason for the fact, but only the fact. Planets are not near because they do not twinkle, but because they are near they do not twinkle. We can arrive at *scientia proper quid* by rearranging the syllogism so that the cause, nearness, constitutes the middle term: the planets are near, therefore they do not twinkle. This provides the proximate cause (nearness) and therefore the reason for the fact that planets do not twinkle. For Grosseteste, therefore, science is properly a search for abstracted universal or

[54] Crombie 1953 (n. 3), 53 n. 4.

principle causes, or reasons, for effects, that knowledge coming through demonstration.

How was knowledge of these principle causes to be achieved? Aristotle maintained that the attainment of the knowledge of these principles was through an inductive (or abstractive) and then deductive process.[55] The enquirer was to begin with what was first in the order of our knowledge, namely facts (*quia*) which were observed in experience. From this, inductive inferences were to be made to more general principles or forms of causes which were removed from the experience of singulars. However, these more general principles are the causes of particular experiences and therefore they are prior in the order of nature. These principles, being prior in the order of nature, could then be the basis for a deductive inference to the explanation and demonstration of observed facts (*propter quid*). On the role and importance of sense perception within this scheme, Aristotle comments that,

> . . . demonstration proceeds from universals and induction from particulars; but it is impossible to gain a view of universals except through induction . . . and we cannot employ induction if we lack sense-perception, because it is sense perception which apprehends particulars.[56]

Coupled to this process of induction and deduction is one of 'resolution' and 'composition'.[57] As an example of this method at work, Crombie describes how Grosseteste's successors, amongst them Roger Bacon, sought to describe the 'common nature' of the colours of the spectrum.[58] Beginning with the enumeration of 'composite' phenomena in which the colours of the spectrum were observed (for example, rainbows, water spray, lenses, iridescent feathers, and so on), these were 'resolved' into the simpler set of attributes common to them all. Thus the 'common nature' of rainbows, sprays and transparent containers of water producing the colours of the spectrum was 'colours produced by differential refraction'. Meanwhile, the more general common nature of the various phenomena producing the colours of the spectrum was found to be 'colours produced by the

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[55] Aristotle, *Posterior Analytics*, I.2.

[56] Ibid., I.18.81b1-16. All translations are by H. Tredennick in the Loeb Classical Library Edition (Cambridge 1989). See also I.31 where Aristotle explains that "scientific knowledge cannot be acquired by sense-perception."

[57] Grosseteste, *Commentarius*, II.4, 256 ff.

[58] Crombie 1953 (n. 3), 64 ff. Grosseteste himself adopts this method in investigating the 'definition' or nature common to horned animals. See Grosseteste, *Commentarius*, II.4, 381 ff.

weakening of white light.'[59] This process of resolution is essentially a process of simplification. By contrast, beginning with this 'resolved hypothesis', the process of 'composition' forms a more complex hypothesis. For example, in the case of the colour of the spectrum, the rainbow was a member of that most general class which produces the colours by the weakening of white light in differential refraction. It is now possible to be more specific and add that in the rainbow this differential refraction occurs through spherical drops of water, and moreover that these drops occur in very large numbers through rain. This process continues until "the aggregate of *differentiae* become convertible with the rainbow itself", and one arrives at an appropriate causal definition.[60]

However, Crombie claims that Grosseteste was well aware that within the process of resolution, broadly coterminous with inductive reasoning, there are two related assumptions or intuitive leaps at work.[61] First, there is the assumption that when one phenomenon is observed to precede and be connected to a second phenomenon, the former is in truth the cause of the latter. Secondly, there is the assumption that general principles (for example, that the appearance of the colours of the spectrum is the weakening of white light) apply in all particular instances (for example, the appearance of this particular rainbow).[62] With reference to the difficulty raised by this first variety of inductive leap, Grosseteste writes as follows:

> Can the cause be arrived at from knowledge of the effect with the same certainty as the effect can be shown to follow from its cause? Is it possible for one effect to have many causes? If one determinate cause cannot be reached from the effect, since there is no effect which has not some cause, it follows that an effect, when it has one cause, may have another, and so there may be several causes of it.[63]

Crombie goes on to claim that Grosseteste introduces experimental verification and falsification to mitigate these difficulties. Having begun

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[59] Crombie 1953 (n. 3), 65.

[60] Ibid., 66.

[61] Ibid., 71 (and n. 3).

[62] The first of these assumptions refers to 'intuitive induction' (one has to intuit a link between cause and effect). The second refers to 'enumerative induction' (one cannot provide a fully exhaustive account of the link of cause and effect between observed particulars and so must assume the uniformity of nature).

[63] Grosseteste, *Commentarius*, II.5, 9-14: "an ex causato sequatur sua causa, sicut ex causa sequitur causatum, an contingat unius plures esse causas. Si enim ex causato non sequitur causa una determinata, cum non sit causatum quin habeat causam aliquam, sequitur quod causatum, cum habeat causam, habeat unam cum causa alia, et ita quod illius sint cause plures." (cited and translated in Crombie 1953 (n. 3), 81).

with 'facts' given by the senses, and having reasoned about those facts through resolution and then composition to arrive at the reason for the facts, it is still necessary to return once again to observation to eliminate false causes or confirm true causes. Aristotle had himself admitted the need for the verification of theory when he wrote that "credit must be given rather to observation than to theories, and to theories only if what they affirm agrees with the observed facts."[64] Crombie claims that Grosseteste adds to Aristotle's thought in advocating falsification as well as verification, and in the development of the method of verification and falsification into 'a systematic experimental procedure' which assumes, first, that the forms of nature always act in a uniform way so that the same cause will always produce the same effect, and, secondly, that the principle of economy in seeking the *propter quid* of natural phenomena is a real principle of nature itself.[65] This method was developed and utilised in investigations into the nature of stars and comets, optics and astronomy.[66]

It is within the theological context of the implications of the Fall for human knowledge that Grosseteste, in his commentary on the *Posterior Analytics*, advocates what Crombie regards as an experimental method.[67] He argues that an abstraction from many singulars must be made before one can arrive at a universal concept. For example, "when someone many times sees the eating of scammony and the accompanying discharge of red bile and he does not see that scammony attracts and draws out red bile, then from the frequent perception of these two visible things [he/she] begins to form a notion of the third, invisible element, that is [in this case] that scammony is the cause that draws out red bile."[68] Once the reason is awakened, the memory leads the reason to conduct an experiment by giving someone scammony to eat after all other causes of

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[64] Aristotle, *Generation of Animals*, III.10.760.b31. All translations are by H. Tredennick in the Loeb Classical Library Edition (Cambridge 1953). In the *Posterior Analytics*, Aristotle writes that ". . . if by observing repeated instances we had succeeded in grasping the universal, we should have our proof; because it is from the repetition of particular experiences that we obtain our view of the universal." (I.31.88a ff.).

[65] Crombie 1953 (n. 3), 84 ff.

[66] Grosseteste, *De Generatione Stellarum* and *De Cometis*, discussed in detail in Crombie 1953 (n. 3), 87-90.

[67] Grosseteste, *Commentarius*, I.14, 247-271.

[68] Ibid., I.14, 256 ff.: ". . . cum videt quis frequenter comestionem scammonee et comitantem egestionem cholere rubee et non videt quod scammonea attrahit et educit rubeam choleram, ex frequenti visione horum duorum visibilium incipit estimare tertium invisibile, scilicet, quod scammonea est causa educendi choleram rubeam."

red bile have been isolated and removed, "and this is the way by which one proceeds from sensation to an experimental universal principle."[69]

Grosseteste here outlines an experimental procedure which requires both the exclusion of possible causes not included in a central hypothesis, and repeated observation. Although this example of experimental procedure which refers to scammony was derived from Avicenna, Crombie sees in Grosseteste's method an attempt to overcome a 'logical hiatus' in scientific procedure which is highly reminiscent of modern Humean concerns. Crombie claims that Grosseteste knew that a gap had to be traversed between, on the one hand, the assertion of a formal definition or a regularly occurring series of events, and on the other hand, the assertion of a theory stating a universal and causal connection. He writes that

> to leap this gap in the logical process of induction he envisaged an act of intuition or scientific imagination, corresponding to Aristotle's *nous*, by which the mind reflecting on the classification of facts produced by induction suddenly grasped a universal or principle or theory explaining the connection between them.[70]

However, as Eileen Serene has argued, there are some significant problems in Crombie's analysis of Grosseteste's thought concerning experiment and induction.[71] In outlining these difficulties, it will be seen both that Grosseteste is faithful to the doctrine of Neoplatonic illumination in his scientific methodology, and that experimental practice, when appropriately placed within the hierarchy of sciences, is highly conducive to his theological cosmology.

In her analysis of Crombie's reading of Grosseteste, Serene notes that there are two distinct ways of understanding induction within Aristotelian science.[72] The first she calls the orthodox view which holds that induction is a necessary but not sufficient condition for the apprehension of first principles. This is to say that something has to be 'added' to induction in order to arrive at first principles. Typically, those who read Aristotle as holding this view of induction claim that *nous* is that which is added to intuitive induction in order to arrive at first principles. However, a scepticism arises (anticipating that of Hume) because this leap of *nous* is not self-justified and its content is not clear. By contrast, Serene prefers

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[69] Ibid., I.14, 270-1: "Et hec est via qua pervenitur a sensu in principium universale experimentale."

[70] Crombie 1953 (n. 3), 71.

[71] E. Serene, *Robert Grosseteste on Induction and Demonstrative Science*, in: Synthese, 40 (1979), 97-115.

[72] Ibid., 100. See Aristotle, *Posterior Analytics*, II.19.

to ascribe to Aristotle the 'empiricist' view of the inductive procedure which states that induction is a sufficient condition in the apprehension of first principles. On this understanding, induction requires nothing added to it, but is instead a *state* of the enquirer. Therefore, an alternative reading of Aristotle's view of this matter would not regard *nous* as something added to induction, but rather as a state of the knower. Serene quotes Barnes to the effect that "*nous*, the state or disposition, stands to induction as understanding (*episteme*) stands to demonstration. Understanding is not a means of acquiring knowledge. Nor, then, is *nous*."[73]

Serene rightly suggests that Crombie ascribes the so-called orthodox view of induction to Grosseteste, in which something is added to induction in order to arrive at first principles.[74] In the orthodox interpretation of Aristotle, that which is added is understood as *nous*, and it is, according to Crombie, replaced in Grosseteste's thought by divine illumination.[75] Moreover, according to Crombie, Grosseteste makes a distinction described above between intuitive and enumerative induction.[76] The former relates to the supposition that actual causal connections cannot in practice be observed: all we observe are the conjunctions of phenomena, so in addition to our observations we must add a leap of intuition to form first universal principles relating cause to effect. The latter enumerative induction relates to the supposition that one can form a generalised universal principle about a genus or species from a limited set of observations. This form of induction therefore requires the assumption that nature is uniform. It seems that Grosseteste did indeed hold to this assumption of nature's uniformity.[77]

Because the assumption of the uniformity of nature mitigated the problem of enumerative induction, Crombie argues that for Grosseteste the

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[73] Ibid., 101, quoting J. Barnes, *Aristotle's Posterior Analytics* (Oxford 1975), 256-7. See also L. M. de Rijk, *Aristotle: Semantics and Ontology*, Leiden 2002, esp. vol. I, 140-159, 637 ff., 648 ff.

[74] See, for example, Crombie 1953 (n. 3), 71: "To leap this gap in the logical process of induction he [Grosseteste] envisaged an act of intuition or scientific imagination, corresponding to Aristotle's νους, by which the mind reflecting on the classification of facts produced by induction suddenly grasped a universal or principle or theory explaining the connexion between them."

[75] See Crombie 1953 (n. 3), 57.

[76] See n. 62. Serene 1979 (n. 71), 105-6 argues that neither Aristotle nor Grosseteste make this distinction. My concurrence with her criticism of Crombie's distinction will be evident shortly.

[77] See Grosseteste, *De Generatione Stellarum* (ed. Baur, 32) cited in Crombie 1953 (n. 3), 85.

problem of induction was focussed principally on the intuitive variety where one could not directly observe the connections linking supposed causes with certain effects. Also, Crombie understands Grosseteste's notion of induction to consist in a 'leap' which requires something in addition to intuitive induction in order to arrive at first principles, this being divine illumination in Grosseteste's thought. Within this context, a very modern looking scepticism apparently arises concerning the validity of this leap and the conclusions which may be reached. Given that the action of cause on effect cannot be directly observed, the natural philosopher is faced with the need to distinguish between a number of causes which in theory could be linked to a given effect.[78] To mitigate this scepticism, Grosseteste apparently adopts two strategies. The first and most important is to include positively by verification *and* exclude by falsification some possible causes of given effects. This is the purpose of the *experimentum* and, according to Crombie, this is the significant move by Grosseteste towards a modern scientific approach to nature. However, a number of possible explanatory causes may survive the process of falsification, so a second strategy must be adopted in order to assuage the apparent inductive scepticism. This strategy is the invocation of the principle of parsimony whereby one always opts for the simplest explanatory cause available.[79] However, these strategies are not in themselves sufficient to achieve the Aristotelian goal of providing the uniquely necessitating causes of particular effects. Therefore, scientific conclusions are always revisable and probable, and experiment must forever continue in order to mitigate both intuitive and enumerative inductive scepticism.

Following the criticisms of Serene, it is now possible to examine some of the weaknesses of Crombie's account. First, and perhaps most importantly, if Crombie is correct in ascribing to Grosseteste the orthodox view of induction (or 'abstraction—he uses the words interchangeably), then Grosseteste has abandoned a thoroughgoing theory of knowledge as divine illumination, and, at the same time, provided the means of separating natural philosophy from theology. This is because, according to the orthodox view of induction, something has to be *added* to the inductive inference in order to arrive at first principles. This establishes a dualism which separates observation by the senses and the induction in the human mind—which we might refer to as *scientia quia*—from the explanatory con-

[78] See n. 63 above. See Grosseteste, *Commentarius*, II.5, 9-14.
[79] See Crombie, 1953 (n. 3), 85 ff.

clusions which may be attained—what we may refer to as *scientia propter quid*. So divine illumination is invoked as *an addition* from *outside* to an otherwise autonomous abstraction from observed phenomena. In other words, the theological doctrine of truth as irradiation in the divine light is introduced to mitigate a weakness in a distinctive and autonomous form of knowing which otherwise makes no reference to divine illumination.

Having made this distinction between the intuitive or abstractive grasp of phenomena and that which is added, namely divine illumination, Serene points out that Crombie is able to make a further distinction between Grosseteste's supposed theoretical and practical responses to the problem of intuitive induction.[80] The theoretical response is to suppose that all certain knowledge is provided by divine illumination and this was the only source of metaphysical certainty as this light was added to our inductive grasp of phenomena. The practical response was to engage in an *experimentum* (such as that relating to scammony and red bile described above) which assumed the uniformity of nature and the principle of parsimony as well as seeking to verify and falsify explanatory hypotheses within controlled observations. Once again, this appears to constitute a tacit separation of natural philosophy from theological accounts of truth: the former adopts a 'practical' response and the latter a 'theoretical' response.

Could this be Grosseteste's view? Surely not. Serene is right to resist the ascription of the orthodox view of induction to Grosseteste. Divine illumination cannot be *added* to observation and inductive or abstractive knowledge of particulars, because the latter, as we have seen, is just as much the result of irradiation by the divine light. All knowledge and being are forms of light which have their origin in the supreme light—the ideas—of God. The knowledge which comes from the inductive or abstractive process is itself the effect of the species which emanate from every creature, each creature itself being a more or less rarefied from of light. The soul, into which sense perceptions enter to be gathered into the memory, is a form of dynamic and spiritual light. All of this is a more or less spiritual form of divine illumination, so divine illumination could not be 'added' to inductive or abstractive knowledge of particulars as if it were something juxtaposed. As Serene tacitly suggests, divine illumination could only be the state of knowledge which one has after a successful induction. To paraphrase Barnes, divine illumination stands to

[80] Serene 1979 (n. 71), 102. See Crombie 1953 (n. 3), 134.

induction as understanding stands to demonstration. Understanding is not a means of acquiring knowledge. Nor, then, is divine illumination, for divine illumination *is* knowledge.

Serene makes some interesting distinctions between Aristotelian *nous* and divine illumination which might clarify Grosseteste's view further.[81] As has been seen, Crombie equates these two in his analysis. However, Aristotle merely claims that we are in a state of *nous* if we have a genuine grasp of a first principle, but not every such impression of a sure grasp of a first principle might be termed *nous*. In the case of divine illumination, all knowledge is somehow analogically related to the first and supreme light, so, as Serene claims, this admits of degrees in a way that *nous* does not. In the above analysis of the distinction between illumination by the supreme light in the beatific vision and illumination by the *lux creata*, the degrees of illumination or knowledge were described in terms of temporality and motion. Here there is no dualism, but a clear distinction, between knowledge and ignorance. This suggests something important about Grosseteste's conception of natural philosophy.[82] Because of this doctrine of illumination, for Grosseteste all knowledge will always be provisional and corrigible until we finally arrive at the beatific vision. This includes knowledge of nature because complete knowledge of creatures is found in contemplation of their exemplars in the divine ideas.[83] By contrast, Serene points out that Aristotelian *nous*, which is the highest form of knowledge, is possible more immanently in such a way that our knowledge is only corrigible when it is mistaken. For Grosseteste, our knowledge is corrigible even, or especially, when it is correct, because this knowledge can always be further irradiated by the supreme light of God to which it is analogically related by participation.

What, then, is the place of the *experimentum* is Grosseteste's schema? If we are to understand the role of experiment, we must first remember the context in which Grosseteste produces the much-quoted example of the eating of scammony and the production of red bile. In this passage, he has just considered the effects of human sin and weakness on knowledge and illumination. The soul requires awakening by the motions of sense perception. This suggests the importance of considered or controlled observation of phenomena. It is the temporal motions of repeated observations which awaken the soul to form universal principles from observed sin-

[81] Serene 1979 (n. 71), 110-2.
[82] The following point is made by Serene 1979 (n. 71), 111.
[83] See Grosseteste's beautiful illustration of this in *De Veritate*, 142.

gulars by the light of the divine. Repetition of experiment is not important because of the need to overcome the problem of enumerative induction, but simply because our souls are asleep and require rousing. However, although this involves the motion from ignorance to knowledge, it is analogously related to the changeless and intuitive grasp of all things in the beatific vision. The *experimentum* is not then a different *kind* of knowledge, but a different *degree* of knowledge which will pass away once the effects of the Fall are assuaged by divine grace. Experimental practice provides a knowledge which is still analogically related to illumination in the beatific vision in such a way that natural philosophy and theology are not separated. Moreover, the *experimentum* is not the criterion of truth for Grosseteste, but merely the first and very important step on the way to a fuller and more scintillating illumination. It provides a knowledge which, although correct and true (but, importantly, not merely probable), is corrigible and capable of being filled with ever greater light. Grosseteste rightly places knowledge from the senses in *experimenta* in an appropriate context:

> It is not in sensation that we know; but it is as a result of sensation that knowledge of the universal comes to us. This knowledge comes to us via the senses, but not from the senses.[84]

Finally, it is important to note that the *experimentum* makes supreme sense within a theological doctrine of divine illumination. Under the so-called orthodox view of induction in which something must be added to an inductive inference and that process justified, a Humean scepticism will always remain concerning the legitimacy of this reasoning. This scepticism is due to an unbridged dualism between the inductive abstraction of universals from singulars (sense perception), and the knowledge that is gained from that perception. Under Grosseteste's doctrine of illumination, the inductive abstraction is analogically related to knowledge and being through the mediation of light. There is no 'chasm' of dark ignorance to be traversed between sensation and knowledge, for the whole is filled with light. Thus the practice of experimental observation is integrated into this theological vision, yet its appropriate place is maintained in the hierarchy of analogically related science. Its truth is a result of irradiation from a higher light, and yet it will pass away at the *eschaton*.

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[84] Grosseteste, *Commentarius*, I.18, 205-7: "non ergo sentiendo scimus, sed occasione ipsius sensus coaccidit in nobis cognitio universalis et scientia, non gratia sensus."

Conclusion

In one important respect, therefore, Grosseteste is not a proto-modern experimental scientist: his motivation for advocating the *experimentum*. There is not a problem *per se* with observation: it is not as if observation is untrustworthy, deficient or plagued by the *aporia* of induction. On the contrary, observation is advocated as the very means of assuaging our inability to see with greater intuition the truth which shines in every aspect of creation.

Moreover, Grosseteste does not advocate the use of mathematics in a way that anticipates the later 'mathematization' of nature (often associated with the Oxford Calculators in the fourteenth century and Galileo, Newton and Descartes in the sixteenth and seventeenth centuries), namely the emphasis on quantity rather than quality, and indeed the quantification of qualities. For Grosseteste, mathematics forms a mediatory bridge between the observations of moving nature and the science of metaphysics. Mathematics is not principally concerned with quantities, but with the quality of proportion and ratio and therefore with relation, harmony and beauty, as seen, for example, in the relative infinities which describe the extension of a simple point of light into a *uni*verse.

Grosseteste's thought is therefore of interest not because he is curiously *avant garde*, but because, through a doctrine of creation and understanding of truth which place light at their core, he offers light as an analogical means of relating distinct sciences. Whereas contemporary discussions of the relationship between science and religion tend to focus upon their common narrative structure or upon religion's forays into the mysteries which science leaves behind, Grosseteste offers a different view: a concept—namely, light—which is common by analogy to physics and theology. Other such concepts which now belong more exclusively to a wholly autonomous science were once understood in more explicitly theological terms: space, time or motion, for example. Each science offers its own distinct account of each, and yet each is analogically related to a transcendent source. So the bond between natural philosophy and theology might lie not in chance similarities of practice or structure, but in a single guarantee of truth understood as illumination.

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